(12) **United States Patent**
Hasselschwert et al.

(10) **Patent No.: US 9,216,430 B2**
(45) **Date of Patent: Dec. 22, 2015**

(54) **SPRAY DEVICE HAVING CURVED PASSAGES**

(75) Inventors: **Daniel J. Hasselschwert**, Sylvania, OH (US); **Roger T. Cedoz**, Curtice, OH (US)

(73) Assignee: **Carlisle Fluid Technologies, Inc.**, Charlotte, NC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 439 days.

(21) Appl. No.: **13/620,606**

(22) Filed: **Sep. 14, 2012**

(65) **Prior Publication Data**

US 2013/0082120 A1 Apr. 4, 2013

Related U.S. Application Data

(60) Provisional application No. 61/542,019, filed on Sep. 30, 2011.

(51) **Int. Cl.**
B05B 7/02 (2006.01)
B05B 7/08 (2006.01)
B05B 7/24 (2006.01)

(52) **U.S. Cl.**
CPC ***B05B 7/2424*** (2013.01); ***B05B 7/0815*** (2013.01)

(58) **Field of Classification Search**
CPC .. B05B 5/0426; B05B 7/0815; B05B 7/2424; B05B 7/02; B05B 7/0823; B05B 7/0861
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,463,332 A * 7/1923 Parker et al. 239/296
2,614,000 A * 10/1952 Reinhold 239/295
2,814,530 A * 11/1957 Portillo 239/296
3,344,992 A * 10/1967 Norris 239/8
3,396,911 A 8/1968 Norris
3,459,374 A 8/1969 Probst
3,561,677 A * 2/1971 Norris et al. 239/705
3,773,263 A 11/1973 Binoche
4,776,368 A 10/1988 Drozd
6,612,506 B1 9/2003 Huang
6,808,122 B2 10/2004 Micheli
7,028,916 B2 4/2006 Micheli

(Continued)

FOREIGN PATENT DOCUMENTS

CN 1062102 A 6/1992
CN 2347673 Y 11/1999

(Continued)

OTHER PUBLICATIONS

U.S. Appl. No. 12/046,249, filed Mar. 11, 2008, Drozd.

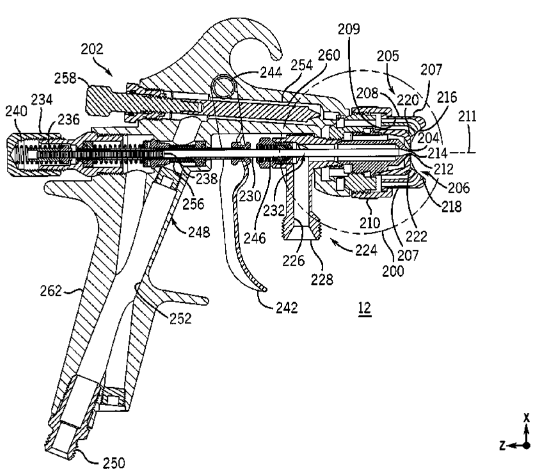
(Continued)

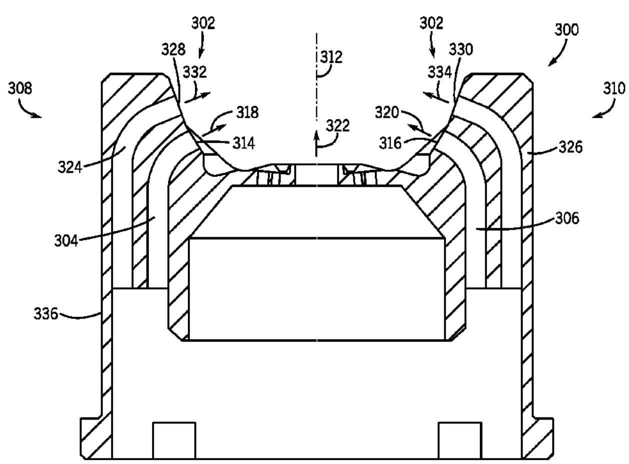
Primary Examiner — Darren W Gorman
(74) *Attorney, Agent, or Firm* — Fletcher Yoder P.C.

(57) **ABSTRACT**

A system includes an air cap configured to mount to a head of a spray device, wherein the air cap comprises at least one air passage having a curved flow path. A system may include a spray head having a first curved air passage that turns inwardly toward a central axis of the spray head, and a second curved air passage that turns inwardly toward the central axis of the spray head, wherein the first and second curved air passage are configured to direct first and second air flows inwardly toward a spray to shape the spray. A system may include a spray device having a liquid passage leading to a liquid outlet, and a curved air passage that gradually curves toward an air outlet.

21 Claims, 5 Drawing Sheets





(56) **References Cited**

U.S. PATENT DOCUMENTS

7,201,336	B2 *	4/2007	Blette et al.	239/601
7,311,271	B2	12/2007	Micheli	
7,568,635	B2	8/2009	Micheli	
7,762,476	B2	7/2010	Micheli	
7,789,327	B2	9/2010	Micheli et al.	
7,926,733	B2	4/2011	Micheli	
7,992,808	B2	8/2011	Micheli	
2004/0031860	A1	2/2004	Micheli	
2004/0046040	A1	3/2004	Micheli	
2004/0262416	A1	12/2004	Micheli	
2005/0006498	A1	1/2005	Micheli	
2006/0000928	A1	1/2006	Micheli	
2006/0065760	A1	3/2006	Micheli	
2006/0214027	A1	9/2006	Micheli	
2007/0221762	A1	9/2007	Micheli et al.	
2008/0017734	A1	1/2008	Micheli et al.	
2008/0048055	A1	2/2008	Micheli	
2008/0185009	A1	8/2008	Chroncholas et al.	
2008/0295768	A1	12/2008	Micheli et al.	
2008/0296409	A1	12/2008	Micheli	
2009/0148612	A1	6/2009	Micheli	
2009/0173809	A1	7/2009	Huang	
2009/0230218	A1	9/2009	Drozd	
2009/0277976	A1	11/2009	Micheli et al.	
2009/0302133	A1	12/2009	Micheli et al.	
2010/0006673	A1	1/2010	Micheli	
2010/0050870	A1	3/2010	Gajjar et al.	
2010/0108784	A1	5/2010	Drozd et al.	

FOREIGN PATENT DOCUMENTS

CN	1485142	A	3/2004
CN	1902002	A	1/2007
DE	9001265		4/1990
GB	1569736		6/1980
RU	2128087	C1	3/1999
RU	2229945	C2	6/2004
RU	2346755	C2	2/2009
WO	2010072775	A1	7/2010
WO	2012168933	A2	12/2012

OTHER PUBLICATIONS

U.S. Appl. No. 12/613,372, filed Nov. 5, 2009, Drozd et al.

U.S. Appl. No. 12/908,656, filed Oct. 20, 2010, Drozd et al.

U.S. Appl. No. 13/356,513, filed Jan. 23, 2012, Micheli et al.

PCT International Search Report & Written Opinion; PCT Application No. PCT/US2012/055830; dated Jan. 22, 2013.

First Chinese Office Action for CN Application No. 201280056188.0, mailed Oct. 9, 2015, 10 pages.

Russian Decision of Grant for RU Application No. 2014117691, issued Aug. 19, 2015, 15 pages.

* cited by examiner

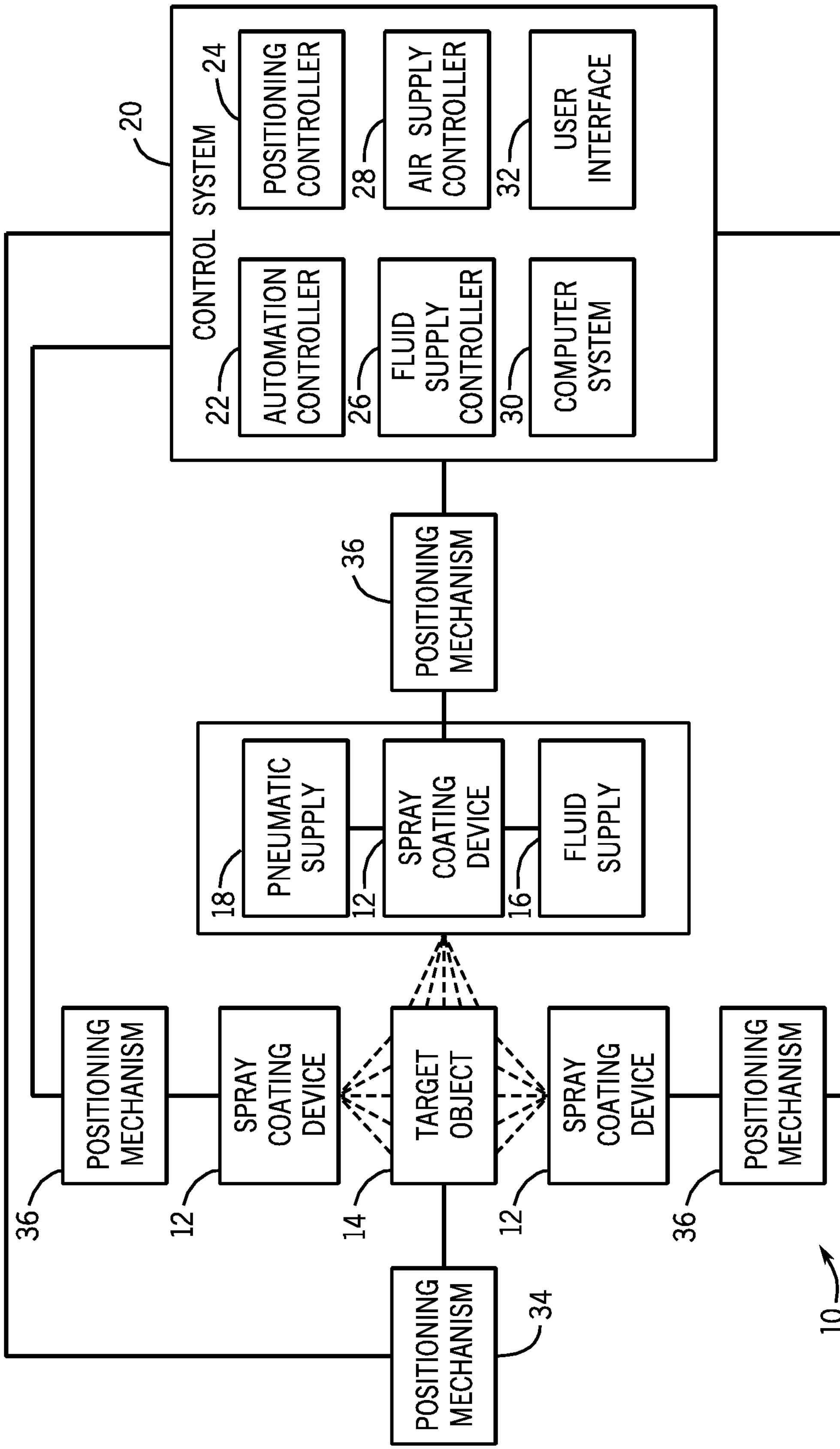
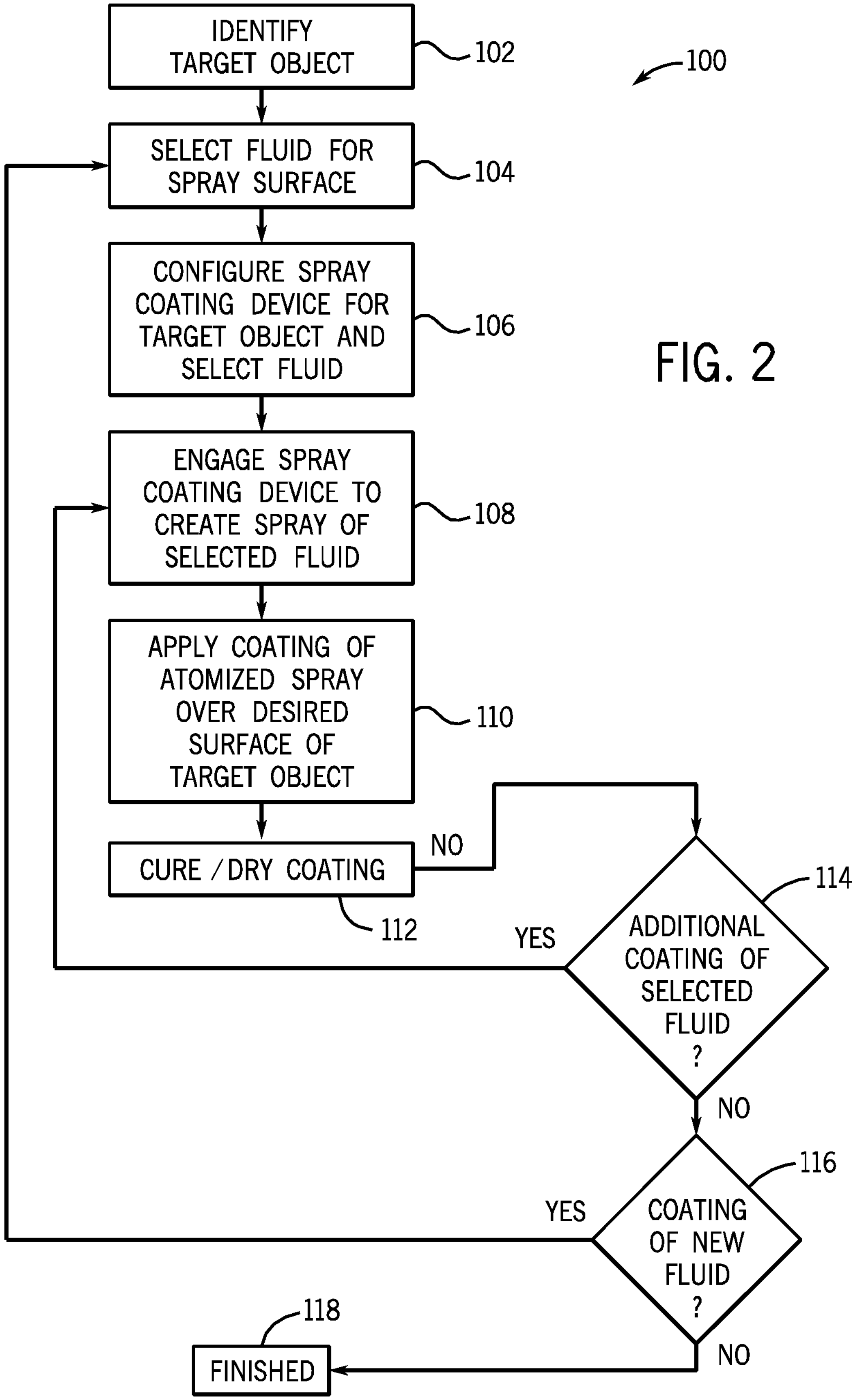

CONTROL SYSTEM
20
POSITIONING CONTROLLER
24
AIR SUPPLY CONTROLLER
28
USER INTERFACE
32
AUTOMATION CONTROLLER
22
FLUID SUPPLY CONTROLLER
26
COMPUTER SYSTEM
30
POSITIONING MECHANISM
36
PNEUMATIC SUPPLY
18
SPRAY COATING DEVICE
12
FLUID SUPPLY
16
POSITIONING MECHANISM
36
SPRAY COATING DEVICE
12
TARGET OBJECT
14
SPRAY COATING DEVICE
12
POSITIONING MECHANISM
36
POSITIONING MECHANISM
34
10

FIG. 1



IDENTIFY TARGET OBJECT
102
100
SELECT FLUID FOR SPRAY SURFACE
104
CONFIGURE SPRAY COATING DEVICE FOR TARGET OBJECT AND SELECT FLUID
106
ENGAGE SPRAY COATING DEVICE TO CREATE SPRAY OF SELECTED FLUID
108
APPLY COATING OF ATOMIZED SPRAY OVER DESIRED SURFACE OF TARGET OBJECT
110
CURE / DRY COATING
112
NO
YES
ADDITIONAL COATING OF SELECTED FLUID ?
114
NO
YES
COATING OF NEW FLUID ?
116
NO
FINISHED
118

FIG. 2

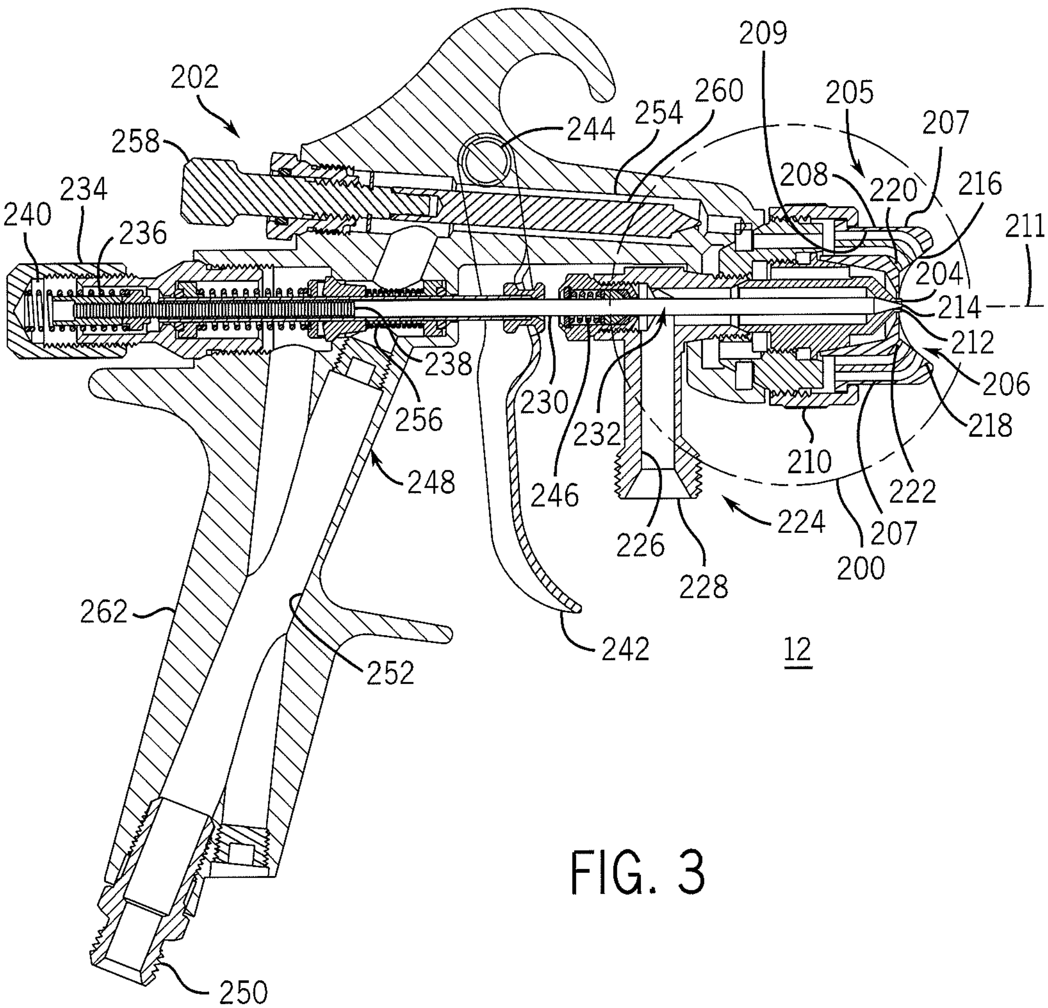

202
258
234
240
236
244
254
260
209
205
207
208
220
216
211
204
214
212
206
218
210
222
207
200
224
228
226
246
232
230
238
256
248
242
262
252
250
12

FIG. 3

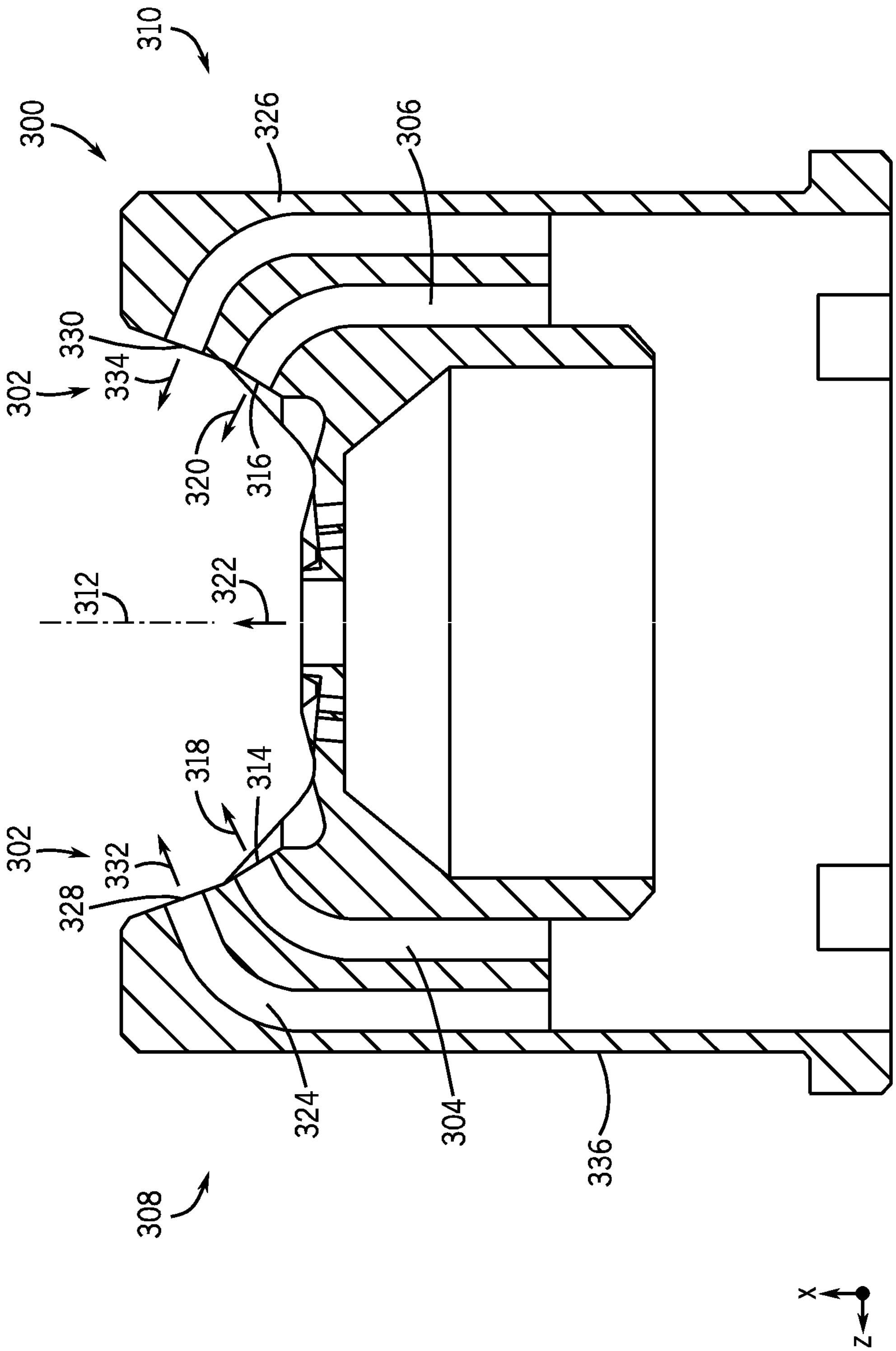

310
300
326
306
330
334
302
320
316
312
322
318
314
302
332
328
324
304
336
308
X
Z

FIG. 4

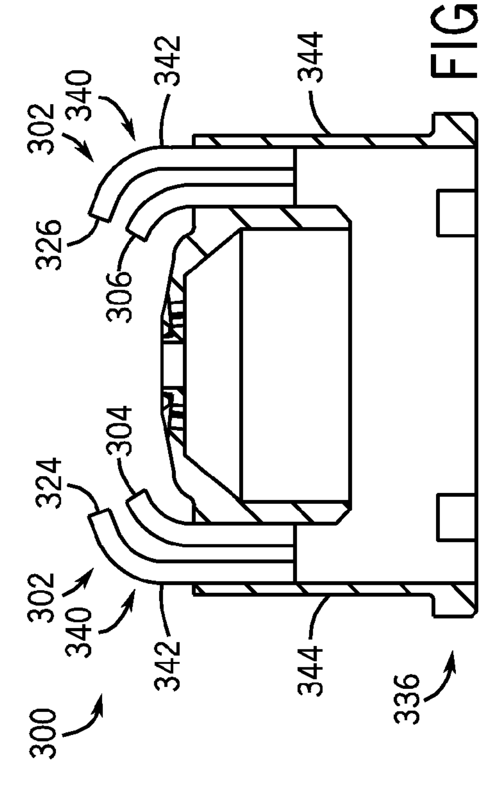


FIG. 5

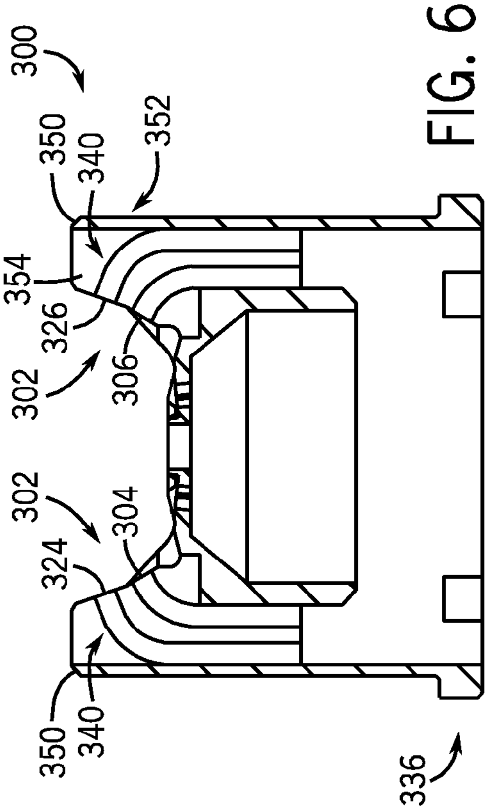


FIG. 6

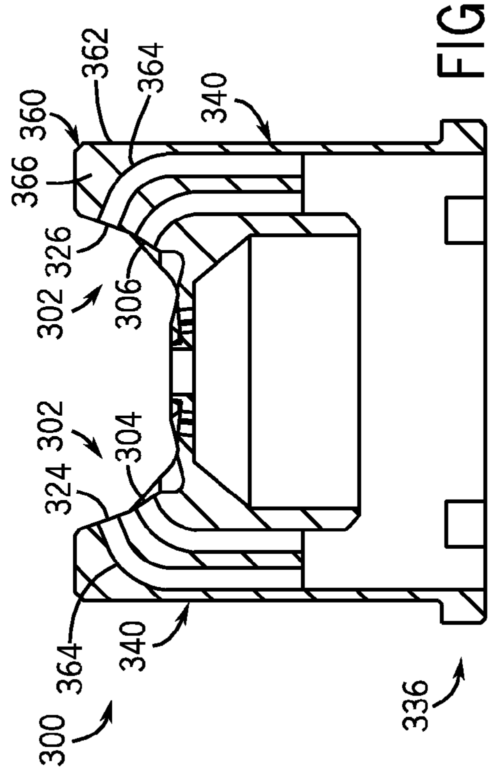


FIG. 7

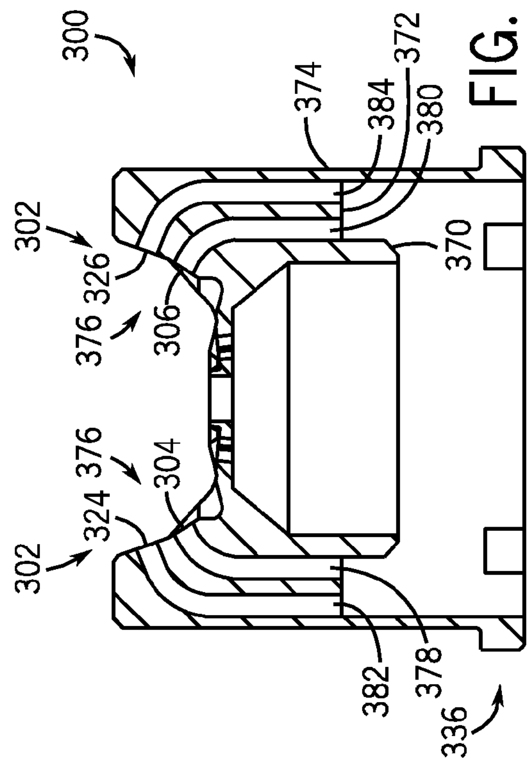


FIG. 8

SPRAY DEVICE HAVING CURVED PASSAGES

CROSS REFERENCE TO RELATED APPLICATION

This application claims priority to and benefit of U.S. Provisional Patent Application No. 61/542,019 entitled "SPRAY DEVICE HAVING CURVED PASSAGES", filed Sep. 30, 2011, which is herein incorporated by reference in its entirety.

BACKGROUND

The invention relates generally to systems and methods for spraying substances, such as coating fluids (e.g., paint).

A variety of spray devices may be used to apply a spray to a target object. For example, spray devices often employ a gas, such as pressurized air, to atomize a liquid (e.g., paint) to generate a spray, which is then directed toward the target object to create a coating. Unfortunately, these spray devices flow the gas (e.g., air) through a series of air passages, which abruptly change in direction before exiting a head of the spray device. For example, the air passages may include a plurality of straight passages (e.g., separately drilled bores) that intersect one another at abrupt angles, which may be 45 to 90 degrees. As a result of these abrupt angles, the spray devices experience significant pressure drop and turbulence in the air flow (e.g., generally degraded air flow), which negatively impacts the spray forming downstream of the head of the spray device. These abrupt angles also generate noise as the air flow must abruptly change in direction. Furthermore, the degraded air flow may cause irregularities, deformities, and general non-uniformity in the spray. As a result, the spray may not provide a uniform coating on a target object. Accordingly, a need exists for an improved spray device.

BRIEF DESCRIPTION

A system includes an air cap configured to mount to a head of a spray device, wherein the air cap comprises at least one air passage having a curved flow path. A system may include a spray head having a first curved air passage that turns inwardly toward a central axis of the spray head, and a second curved air passage that turns inwardly toward the central axis of the spray head, wherein the first and second curved air passage are configured to direct first and second air flows inwardly toward a spray to shape the spray. A system may include a spray device having a liquid passage leading to a liquid outlet, wherein the spray device is configured to atomize a liquid from the liquid outlet to form a spray. The spray device also may include a curved air passage that gradually curves toward an air outlet, wherein the spray device is configured to at least partially shape the spray with an air flow from the air outlet.

DRAWINGS

These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

FIG. **1** is a diagram illustrating an exemplary spray coating system in accordance with certain embodiments of the present invention;

FIG. **2** is a flow chart illustrating an exemplary spray coating process in accordance with certain embodiments of the present invention;

FIG. **3** is a cross-sectional side view of an exemplary spray coating device in accordance with certain embodiments of the present invention;

FIG. **4** is a cross-sectional side view of an embodiment of an air cap having curved passages;

FIG. **5** is a cross-sectional side view of an embodiment of an air cap having curved passages, e.g., curved tubing protruding from a body portion of the air cap;

FIG. **6** is a cross-sectional side view of an embodiment of an air cap having curved passages, e.g., curved tubing surrounded by a protective wall;

FIG. **7** is a cross-sectional side view of an embodiment of an air cap having curved passages, e.g., curved tubing encased within a protective material (e.g., an overmolded material);

FIG. **8** is a cross-sectional side view of an embodiment of an air cap having curved passages, e.g., multiple sections defining the curved passages.

DETAILED DESCRIPTION

One or more specific embodiments of the present invention will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

FIG. **1** is a flow chart illustrating an exemplary spray coating system **10**, which comprises a spray coating device **12** for applying a desired coating to a target object **14**. As discussed in detail below, the spray coating device **12** may include one or more curved passages (e.g., curved air passages) configured to reduce turbulence, pressure, drop, and noise associated with air flow through the spray coating device **12**. Furthermore, the curved air passages may be configured to improve the spray formed by the spray coating device **12**, e.g., by providing a more uniform air flow to shape the spray. In particular, the curved air passages may help uniformly distribute liquid droplets in the spray, thereby helping to increase the transfer efficiency of the spray onto a target object while also providing a more uniform coating on the target object.

In addition, the spray coating device **12** may include features to enable a non-conical spray shape and/or a spray shape characterized by a width that varies in a non-linear manner (e.g., curved manner) from an exit of the device **12** to the target object **14**. In certain embodiments, the spray shape may be characterized by a cup-shaped or concave outer profile or periphery (e.g., outer edges), such that the width and/or cross-section of the spray shape is greater than a conical shape at a distance close to the exit of the spray coating device **12**. In other embodiments, the spray shape may be characterized by a tulip shaped profile or periphery. As discussed below, the unique spray shaping features may enable a greater coverage area with a suitable velocity at a distance close to the exit of the spray coating device **12**, thereby improving transfer efficiency and, thus, reducing waste and pollution. It should be noted that in the context of the present disclosure, the terms "conical" and "non-conical" when used to describe a spray shape are intended to refer to the general shape of the periphery of a cross-sectional view of the spray shape. These terms are not intended to suggest that spray particles travel only along the periphery of the spray shape. Rather, spray particles may indeed be transferred throughout the entire interior space of the spray shape.

The illustrated spray coating device **12** may comprise an air atomizer, a rotary atomizer, an electrostatic atomizer, or any other suitable spray formation mechanism. In certain embodiments, the spray coating device **12** may be described as a spray gun, which may include a gun-shape with a handle portion, a barrel or body portion coupled to the handle portion, and a trigger to engage and disengage one or more valves. However, the unique spray shaping features may be utilized on any type of spray device.

The spray coating device **12** may be coupled to a variety of supply and control systems, such as a fluid supply **16**, an air supply **18**, and a control system **20**. The control system **20** facilitates control of the fluid and air supplies **16** and **18** and ensures that the spray coating device **12** provides an acceptable quality spray coating on the target object **14**. For example, the control system **20** may include an automation controller **22**, a positioning controller **24**, a fluid supply controller **26**, an air supply controller **28**, a computer system **30**, and a user interface **32**.

The control system **20** also may be coupled to one or more positioning mechanisms **34** and **36**. For example, the positioning mechanism **34** facilitates movement of the target object **14** relative to the spray coating device **12**. The positioning mechanism **36** is coupled to the spray coating device **12**, such that the spray coating device **12** can be moved relative to the target object **14**. Also, the system **10** can include a plurality of the spray coating devices **12** coupled to positioning mechanisms **36**, thereby providing improved coverage of the target object **14**. Accordingly, the spray coating system **10** can provide a computer-controlled mixture of coating fluid, fluid and air flow rates, and spray pattern/coverage over the target object. Depending on the particular application, the positioning mechanisms **34** and **36** may include a robotic arm, conveyor belts, and other suitable positioning mechanisms.

FIG. **2** is a flow chart of an exemplary spray coating process **100** for applying a desired spray coating to the target object **14**. As illustrated, the process **100** proceeds by identifying the target object **14** for application of the desired fluid (block **102**). The process **100** then proceeds by selecting the desired fluid **40** for application to a spray surface of the target object **14** (block **104**). The desired fluid may include a base coating fluid, a paint, a clear coat, a stain, and so forth. A user may then proceed to configure the spray coating device **12** for the identified target object **14** and selected fluid **40** (block **106**). The target object **14** may include a vehicle, furniture, appliance, and so forth. As the user engages the spray coating device **12**, the process **100** then proceeds to create an atomized spray of the selected fluid **40** (block **108**). In certain embodiments discussed in detail below, the atomized spray has a non-conical spray shape, such as a cup-shape, a concave shape, or a tulip shape. The user may then apply a coating of the atomized spray over the desired surface of the target object **14** (block **110**). The process **100** then proceeds to cure/dry (e.g., infrared curing lamp) the coating applied over the desired surface (block **112**). If an additional coating of the selected fluid **40** is desired by the user at query block **114**, then the process **100** proceeds through blocks **108**, **110**, and **112** to provide another coating of the selected fluid **40**. If the user does not desire an additional coating of the selected fluid at query block **114**, then the process **100** proceeds to query block **116** to determine whether a coating of a new fluid is desired by the user. If the user desires a coating of a new fluid at query block **116**, then the process **100** proceeds through blocks **104**-**114** using a new selected fluid for the spray coating. If the user does not desire a coating of a new fluid at query block **116**, then the process **100** is finished at block **118**.

FIG. **3** is a cross-sectional side view illustrating an exemplary embodiment of the spray coating device **12**. As illustrated, the spray coating device **12** comprises a spray tip assembly **200** coupled to a body **202**. The spray tip assembly **200** includes a fluid delivery tip assembly **204**. For example, a plurality of different types of spray coating devices may be configured to receive and use the fluid delivery tip assembly **204**. The spray tip assembly **200** also includes a spray formation assembly **206** coupled to the fluid delivery tip assembly **204**. The spray formation assembly **206** comprises an air cap **208**, which is removably secured to the body **202** via a retaining nut **210**. The air cap **208** includes a variety of air atomization orifices, such as a central atomization annular orifice **212** disposed about a fluid tip exit **214** from the fluid delivery tip assembly **204**. The air cap **208** also may have one or more spray shaping orifices, such as spray shaping (e.g., air horn) orifices **216**, **218**, **220**, and **222**, which force the sprayed fluid to form a desired spray pattern (e.g., a non-conical pattern). The spray formation assembly **206** also may comprise a variety of other atomization mechanisms to provide a desired spray pattern and droplet distribution.

As discussed below, the air cap **208** may include curved passages to improve the air flow, reduce turbulence, reduce noise, and improve spray formation downstream of the spray coating device **12**. In the illustrated embodiment of FIG. **3**, the air cap **208** has a plurality of curved air passages **205**, each having a series of curved air passages **207** and **209**. The curved air passages **205** may replace non-curved air passages to improve operation of the spray coating device **12**.

The body **202** of the spray coating device **12** includes a variety of controls and supply mechanisms for the spray tip assembly **200**. As illustrated, the body **202** includes a fluid delivery assembly **224** having a fluid passage **226** extending from a fluid inlet coupling **228** to the fluid delivery tip assembly **204**. The fluid delivery assembly **224** also comprises a fluid valve assembly **230** to control fluid flow through the fluid passage **226** and to the fluid delivery tip assembly **204**. The illustrated fluid valve assembly **230** has a needle valve **232** extending movably through the body **202** between the fluid delivery tip assembly **204** and a fluid valve adjuster **234**. The fluid valve adjuster **234** is rotatably adjustable against a spring **236** disposed between a rear section **238** of the needle valve **232** and an internal portion **240** of the fluid valve adjuster **234**. The needle valve **232** is also coupled to a trigger **242**, such that the needle valve **232** may be moved inwardly away from the fluid delivery tip assembly **204** as the trigger **242** is rotated counter clockwise about a pivot joint **244**. However, any suitable inwardly or outwardly openable valve assembly may be used with embodiments of the present invention. The fluid valve assembly **230** also may include a variety of packing and seal assemblies, such as packing assembly **246**, disposed between the needle valve **232** and the body **202**.

An air supply assembly **248** is also disposed in the body **202** to facilitate atomization at the spray formation assembly **206**. The illustrated air supply assembly **248** extends from an air inlet coupling **250** to the air cap **208** via air passages **252** and **254**. The air supply assembly **248** also includes a variety of seal assemblies, air valve assemblies, and air valve adjusters to maintain and regulate the air pressure and flow through the spray coating device **12**. For example, the illustrated air supply assembly **248** includes an air valve assembly **256** coupled to the trigger **242**, such that rotation of the trigger **242** about the pivot joint **244** opens the air valve assembly **256** to allow air flow from the air passage **252** to the air passage **254**. The air supply assembly **248** also includes an air valve adjustor **258** coupled to a needle **260**, such that the needle **260** is movable via rotation of the air valve adjustor **258** to regulate the air flow to the air cap **208**. As illustrated, the trigger **242** is coupled to both the fluid valve assembly **230** and the air valve assembly **256**, such that fluid and air simultaneously flow to the spray tip assembly **200** as the trigger **242** is pulled toward a handle **262** of the body **202**. Once engaged, the spray coating device **12** produces an atomized spray with a desired spray pattern (e.g., non-conical) and droplet distribution. Again, the illustrated spray coating device **12** is only an exemplary embodiment of the present invention. Any suitable type or configuration of a spraying device may benefit from the unique air cap fluid atomization and air shaping aspects of the present invention.

FIG. **4** is a cross-sectional side view of an embodiment of an air cap **300** having curved passages **302** (e.g., curved air passages). As illustrated, the curved passages **302** include first and second curved air passages **304** and **306** on opposite sides **308** and **310** of a longitudinal axis **312** of the air cap **300**. The first curved air passage **304** curves inwardly toward the longitudinal axis **312** and terminates at a first air outlet **314**. The second curved air passage **306** curves inwardly toward the longitudinal axis **312** and terminates at a second air outlet **316**. In operation, the first and second curved air passages **304** and **306** are configured to direct first and second air flows **318** and **320** toward a spray **322** to shape the spray **322**. As further illustrated, the curved passages **302** include third and fourth curved air passages **324** and **326** on opposite sides **308** and **310** of the longitudinal axis **312** of the air cap **300**. The third curved air passage **324** curves inwardly toward the longitudinal axis **312** and terminates at a third air outlet **328**. The fourth curved air passage **326** curves inwardly toward the longitudinal axis **312** and terminates at a fourth air outlet **330**. In operation, the third and fourth curved air passages **324** and **326** are configured to direct third and fourth air flows **332** and **334** toward the spray **322** to shape the spray **322**.

These curved passages **302** are configured to improve the airflow to the spray **322**, thereby improving the spray **322**. In particular, the curved passages **302** may be configured to reduce turbulence, pressure, drop, and noise associated with air flow through the spray coating device **12**. Furthermore, the curved passages **302** may be configured to improve the spray **322** formed by the spray coating device **12**, e.g., by providing a more uniform air flow to shape the spray **322**. In particular, the curved passages **302** may help uniformly distribute liquid droplets in the spray **322**, thereby helping to increase the transfer efficiency of the spray **322** onto a target object while also providing a more uniform coating on the target object. In the illustrated embodiment, the curved passages **302** include four curved passages. In other embodiments, the curved passages **302** may include any number of curved passages, e.g., 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more, in any suitable symmetrical or non-symmetrical arrangement. Furthermore, the illustrated curved passages **302** gradually curve inwardly toward the axis **312** over an angle of approximately 45 degrees at some radius of curvature. In other embodiments, the curved passages **302** may gradually curve inwardly or outwardly relative to the axis **312** over an angle of approximately 1 to 150 degrees, 5 to 120 degrees, 10 to 100 degrees, 20 to 90 degrees, 30 to 60 degrees, 40 to 50 degrees, or any specific angle therebetween. Furthermore, the radius of curvature of each curved passage **302** may range between approximately 0.1 to 5, 0.2 to 4, 0.3 to 3, 0.4 to 2, or 0.5 to 1 inch, or any other suitable radius of curvature.

The curved passages **302** of the air cap **300** may be formed in a variety of ways. In the illustrated embodiment, the air cap **300** may be a one-piece structure having the curved passages **302** formed integrally with an entire body **336** of the air cap **300**. For example, the entire body **336** may be molded from a plastic material or cast from a metal material to form the air cap **300** with integral curved passages **302**. In other embodiments, the a plurality of separate pieces may define the air cap **300** with the curved passages **302**. For example, the curved passages **302** may be separate pieces (e.g., curved tubing) from the body **336**. By further example, the curved passages **302** may be formed with multiple segments or sections of the body **336**. Regardless of the manufacturing technique, the curved passages **302** provide a gradual curvature devoid of any abrupt changes in angle. In other words, the curved passages **302** do not experience any abrupt angles attributed to multiple straight passages intersecting one another.

FIG. **5** is a cross-sectional side view of an embodiment of the air cap **300** having curved passages **302**, e.g., curved tubing **340** protruding from the body **336** of the air cap **300**. In the illustrated embodiment, each curved tubing **340** may be a separately formed tubing with a tubular wall **342**, which gradually curves to form the curved passage **302** (e.g., curved passages **304**, **306**, **324**, and **326**). For example, each curved tubing **340** may be a metal tube, a plastic tube, a ceramic tube, a composite tube, or any suitable material defining a tube. In an embodiment having a metal curved tubing **340**, the tubing **340** may be formed and then bent to a desired curvature. In an embodiment having a plastic tubing **340**, the tubing **340** may be molded to define the desired curvature. However, any suitable construction of the curved tubing **340** may be employed in various embodiments. As illustrated, the curved tubing **340** protrudes away from the body **336**, and is secured to the body **336** by a suitable mount **344**. The mount **344** may include a removable or fixed fastener, such as a screw, bolt, clamp, adhesive, strap, snap-fit mechanism, latch, or any other suitable fastener. The mount **344** also may include an integral connection with the body **336**, such as an overmolded material (e.g., plastic) around the tubing **340**.

FIG. **6** is a cross-sectional side view of an embodiment of the air cap **300** having curved passages **302**, e.g., curved tubing **340** surrounded by a protective wall **350**. For example, the protective wall **350** may define a hollow enclosure or casing **352**, which generally surrounds the curved tubing **340** without directly contact each entire curved tubing **340**. In other words, the protective wall **350** retains a hollow interior **354**, and each curved tubing **340** generally passes through the hollow interior **354**. In certain embodiments, the protective wall **350** may be made of a metal, plastic, ceramic, or composite material. Accordingly, the embodiment of FIG. **6** has a multi-piece construction of the protective wall **350** and each curved tubing **340**.

FIG. **7** is a cross-sectional side view of an embodiment of the air cap **300** having curved passages **302**, e.g., curved tubing **340** encased within a protective material **360** (e.g., an overmolded material) of the body **336**. For example, the protective material **360** may define a solid structure **362** (e.g., non-hollow structure), which generally contacts each curved tubing **340** directly along its exterior surface **364**. In other words, the protective material **360** retains a solid interior **366**, and each curved tubing **340** generally passes through the solid interior **366**. In certain embodiments, the protective material

360 may be made of a metal, plastic, ceramic, or composite material. For example, the curved tubing **340** may be molded, or overmolded, in place by a mold material (e.g., a plastic), such that the curved tubing **340** is substantially or entirely encapsulated and fixed in place by the mold material. Accordingly, the embodiment of FIG. **7** has a multi-piece construction of the protective material **360** and each curved tubing **340**.

FIG. **8** is a cross-sectional side view of an embodiment of the air cap **300** having curved passages **302**, e.g., multiple sections **370**, **372**, and **374** defining the curved passages **302**. For example, each curved passage **302** may be formed as a curved groove **376** along an exterior surface of one of the sections **370**, **372**, or **374**, and then the sections **370**, **372**, and **374** may be subsequently coupled together to define the body **336** of the air cap **300**. In the illustrated embodiment, for example, the section **370** may be a first annular (or inner) section having curved grooves **376** (e.g., first and second curved grooves **378** and **380**) along a first exterior surface. Similarly, the section **372** may be a second annular (or intermediate) section having curved grooves **376** (e.g., third and fourth curved grooves **382** and **384**) along a second exterior surface. Finally, the section **374** may be a third annular (or outer) section surrounding the sections **370** and **372**. In this manner, the curved grooves **376** may be formed along an exterior surface to simplify manufacturing, servicing, and so forth.

While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

The invention claimed is:

1. A system, comprising:
- an air cap configured to mount to a head of a spray device, wherein the air cap comprises:
  - a first shaping air passage having a first curved flow path and a first outlet, wherein the first shaping air passage curves inwardly toward a central axis of the air cap; and
  - a second shaping air passage having a second curved flow path and a second outlet, wherein the second shaping air passage curves inwardly toward the central axis of the air cap;
  - wherein the first outlet and the second outlet are at different axial positions.

2. The system of claim **1**, wherein at least the first or second shaping air passages comprise a curved tubing.

3. The system of claim **2**, wherein the curved tubing is at least partially surrounded by a protective wall.

4. The system of claim **2**, wherein the curved tubing is at least partially encased by a protective material.

5. The system of claim **4**, wherein the protective material is an overmolded material.

6. The system of claim **1**, wherein the air cap is a one-piece structure having the first and second shaping air passages.

7. The system of claim **1**, wherein the air cap is a multi-piece structure having the first and second shaping air passages.

8. The system of claim **7**, wherein a first piece of the multi-piece structure defines the first shaping air passage, and a second piece of the multi-piece structure at least partially surrounds the first piece.

9. The system of claim **1**, wherein the first and second air passages are configured to direct an air flow toward a spray to shape the spray.

10. The system of claim **1**, wherein the first and second shaping air passages are on opposite sides of a longitudinal axis of the air cap, and the first and second shaping air passage are configured to direct first and second air flows toward a spray to shape the spray.

11. The system of claim **10**, comprising third and fourth shaping air passages on the opposite sides of the longitudinal axis of the air cap, the third shaping air passage comprises a third curved flow path that curves inwardly toward the longitudinal axis, the fourth shaping air passage comprises a fourth curved flow path that curves inwardly toward the longitudinal axis, and the third and fourth shaping air passages are configured to direct third and fourth air flows toward the spray to shape the spray.

12. The system of claim **1**, comprising the spray device having the air cap.

13. The system of claim **12**, wherein the spray device comprises an air valve configured to control an air flow through the first and second shaping air passages.

14. The system of claim **12**, wherein the spray device comprises a liquid passage leading to the head of the spray device, and the spray device is configured to atomize the liquid to generate a liquid spray.

15. The system of claim **13**, wherein the spray device comprises a liquid valve configured to control a liquid flow through the liquid passage.

16. The system of claim **12**, wherein the spray device comprises a handle and a trigger configured to control operation of the spray device.

17. A system, comprising:
- a spray head, comprising:
  - a first curved shaping air passage with a first outlet, wherein the first curved shaping air passage turns inwardly toward a central axis of the spray head; and
  - a second curved shaping air passage with a second outlet, wherein the second curved shaping air passage turns inwardly toward the central axis of the spray head, wherein the first and second curved shaping air passages are configured to direct first and second air flows inwardly toward a spray to shape the spray;
  - wherein the first outlet and the second outlet are at different axial positions.

18. The system of claim **17**, wherein the first and second curved shaping air passages comprise respective first and second curved tubing at least partially disposed in a support structure, the support structure comprises at least one of a protective wall or protective material, and the first and second curved shaping air passages protrude outwardly away from the support structure.

19. A system, comprising:
- a spray device, comprising:
  - a liquid passage leading to a liquid outlet, wherein the spray device is configured to atomize a liquid from the liquid outlet to form a spray;
  - a first curved shaping air passage that gradually curves toward a first air outlet and a central axis of the spray device; and
  - a second curved shaping air passage that gradually curves toward a second air outlet and the central axis of the spray device;
  - wherein the first and second outlets are at different axial positions and are configured to at least partially shape the spray with an air flow.

20. The system of claim **19**, wherein the first and second air outlets are axially offset from the liquid outlet in a downstream direction away from the liquid outlet.

21. The system of claim **1**, wherein the first shaping air passage comprises a first centerline and the second shaping air passage comprises a second centerline, and the first and second shaping air passages comprise respective inner and outer curvatures on opposite sides of the first and second centerlines, wherein the inner and outer curvatures curve towards the central axis of the air cap.

* * * * *